MODULE 6
SUPERCELL STORMS AND TORNADOES

OBJECTIVES

At the completion of this module, the student will be able to:

1) Describe the structure and behavior of supercell thunderstorms
2) Recognize the differences in visual and radar appearance between classic, low-precipitation, and high-precipitation supercells
3) Describe the three stages of the typical tornado life cycle

INTRODUCTION

Supercell storms are strong, long-lived, well organized storms (figure 6-1). They develop in environments characterized by **high instability**, **strong vertical wind shear**, and **veering** (clockwise turning of the wind with height) in the lowest mile or so of the atmosphere. The primary difference between supercells and the non-supercell storms described earlier is the **mesocyclone** - a strong rotation found in the supercell's updraft. The mesocyclone helps stabilize and enhance the storm's updraft enabling it to persist for many hours in some cases. Of course, the mesocyclone's rotation allows the supercell to produce significant tornadoes.

While some supercells produce only one mesocyclone during their lifetime, others may produce one mesocyclone (and tornado) after another. These storms, called **cyclic supercells**, can pose major coordination problems for forecasters and storm spotters. Cyclic supercells have been known to produce up to 9 mesocyclones and tornadoes during their lifetime! By virtue of their strength and organization, supercells will virtually always be severe. Thus, once a supercell has been identified, warning decisions become easier. The challenge, though, is to determine what *type* of warning is needed.

Figure 6-1: Distant supercell, view is to the east. Note the large overshooting top and thick anvil. Note also the upright nature of the supercell's updraft compared to the towering cumulus at right.

CLASSIC SUPERCELL STRUCTURE

The organization of a "classic" supercell is a direct result of the environment in which the storm develops. The storm's updraft is found at the rear of the storm, with precipitation and downdraft in the forward portions. Strong vertical wind shear in the storm's environment results in **sorting** of rain and hail within the precipitation area. Light rain (i.e., the smallest precipitation particles) are found at the leading edge of the storm, with increasing rainfall and hail closer to the updraft. Immediately downstream of the updraft, very large hail (larger than golfball size in most cases) and heavy rain is found.

The mesocyclone (rotating updraft) is located at the **right rear flank** of the storm, when viewed in the storm's frame of movement. The mesocyclone is the area most favored for tornado development. Strong downburst winds and very large hail are also likely in the vicinity of the mesocyclone. Visually, the updraft will be marked by a rain-free cloud base and a wall cloud. The wall cloud will probably be persistent, lasting for 10 minutes or longer, and will probably be visibly rotating. Spotters may also report strong surface winds blowing into the wall cloud area. See Figures 6-2 and 6-3 below for diagrams of a classic supercell.

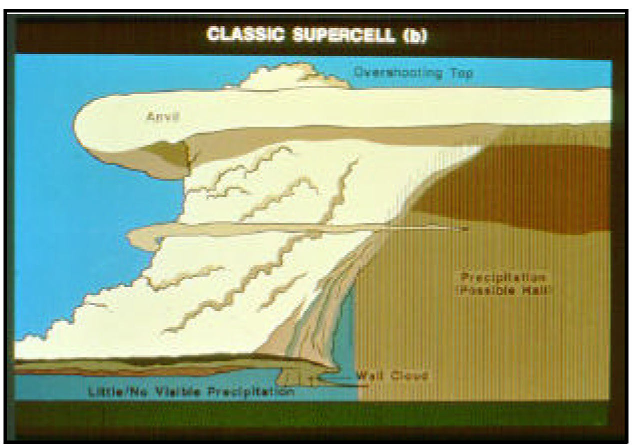


Figure 6-2: Side view diagram of a classic supercell. View is to the west or northwest. Note the wall cloud and overshooting top marking the updraft, with precipitation associated with the downdraft area.

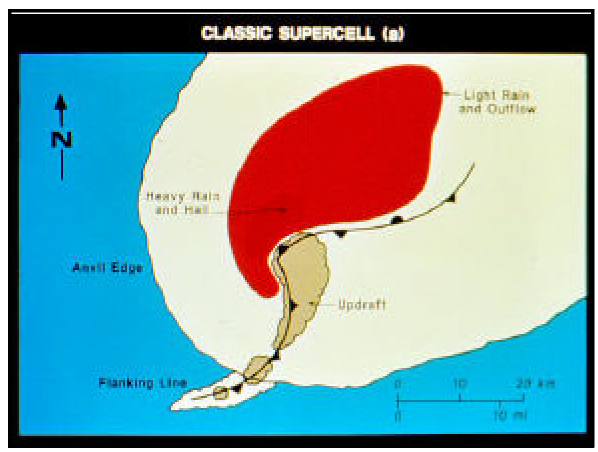


Figure 6-3: Top view diagram of a classic supercell. Storm is moving toward the upper-right. Light stippled area denotes light/moderate rain, dark area just north of updraft marks area of large hail. Frontal boundary indicates position of gust front.

SUPERCELL VARIATIONS

The classic supercell described earlier serves as a baseline when describing variations of the supercell model. Some supercells produce tremendous amounts of rain and hail which fall through and around the mesocyclone. Others produce little liquid precipitation, but tremendous amounts of hail. While many supercells have their updrafts at the rear of the storm, as described above, some storms' mesocyclones are on the forward flank. This can cause serious coordination problems between spotters and radar operators.

Heavy-Precipitation Supercells

Heavy-precipitation (HP) supercells produce torrential rain and hail near the mesocyclone. They are the type of storm most likely to have the mesocyclone on the east or even northeast flank. HP supercells are difficult to observe visually but easier to detect on Doppler radar. The heavy precipitation may obscure the rain-free base and wall cloud, so spotters may have a difficult time observing any tornadoes which develop. However, spotters should be able to observe **striations** in the updraft tower. Striations are streaked formations which give the cloud a corkscrew or barber-pole appearance. Additionally, an **inflow band** may be visible, extending from the updraft tower to the east or northeast along the edge of the precipitation.

The torrential rainfall associated with HP supercells can lead to flash flooding. The abundant precipitation does give plenty of targets for weather radar to detect, as we will discuss in Module 13. Research studies suggest that the HP supercell may be the most common type of supercell nationwide. See Figures 6-4 and 6-5 below for diagrams of an HP supercell.

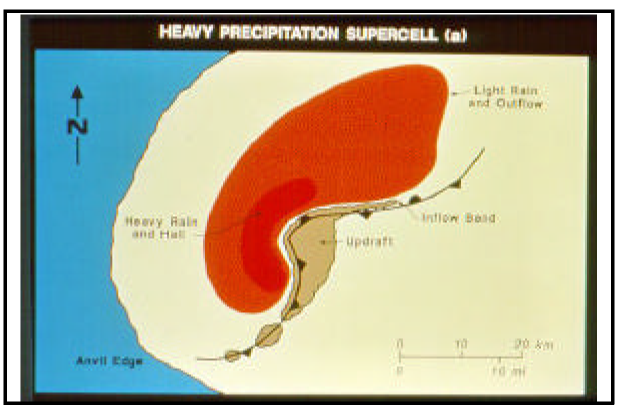


Figure 6-4: Top-view diagram of an HP supercell. Note larger, kidney-bean shaped precipitation area with heavy rain/hail to the southwest of the updraft.

Figure 6-5: Example of an HP supercell. View is to the west. Note the heavy rain and low visibility around wall cloud. Note also the spiraling mid-level cloud bands and the low-level inflow band suggesting the mesocyclone's rotation.

Low-Precipitation Supercells

Low-precipitation (LP) supercells are often found near the dryline but have been documented in other areas as well. LP supercells produce scanty amounts of rain but substantial amounts of (often very large) hail. These storms are difficult to detect on radar because of the lack of rainfall. The updraft in an LP storm is typically found at the rear flank, with the precipitation area to the east or northeast. On radar, the precipitation area will usually not have the characteristic shape seen with the classic or HP supercell.

Spotters observing an LP supercell will usually report an updraft tower which is slender, bell-shaped, or flared out close to the cloud base. Striations may be present on the side of the cloud tower, again giving the storm the appearance of a corkscrew or barber pole. The precipitation area will be fairly light and spotty. In some cases, spotters may be able to see completely through the area. Spotters should not be decived, though; the precipitation area may contain hailstones up to 5 inches in diameter! See Figures 6-6 and 6-7 for diagrams of an LP supercell.

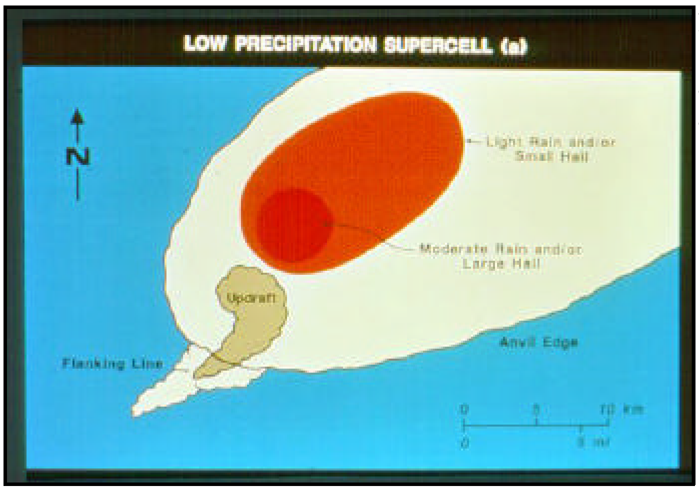
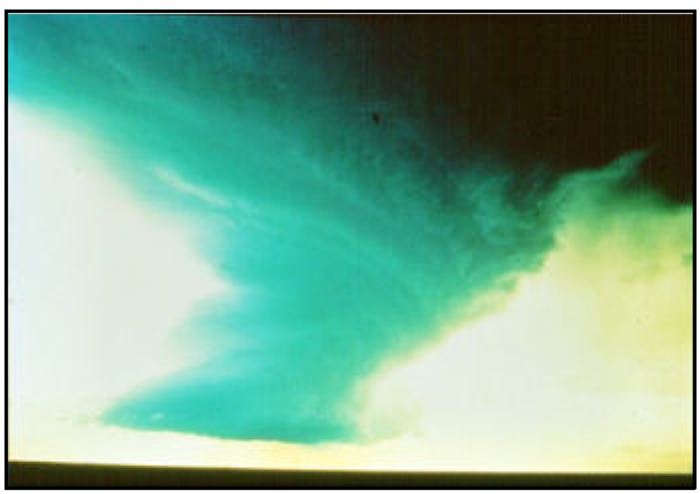


Figure 6-6: Top view diagram of an LP supercell. Note lack of a hook echo and small size of the precipitation area.

Figure 6-7: Example of LP supercell. View is to the west. Note corkscrew appearance to main storm tower and very light precipitation to the north (right) of updraft tower.



TORNADO CLASSIFICATION

A **tornado** is defined as a violently rotating column of air descending from a thunderstorm and in contact with the ground. Tornadoes are classified based on the **Fujita Scale**, an intensity scale developed by Dr. T. Fujita at the University of Chicago. Dr. Fujita's scale extends from F0 to F5, with F5 being the strongest. Tornadoes can also be classified on a broader, three-step scale. Specifics regarding the intensity scales are shown below:

Scale	Class	Est. Wind Speed	Description
F0	Weak	40-73 mph	Gale tornado
F1	Weak	74-110 mph	Moderate tornado
F2	Strong	111-140 mph	Significant tornado
F3	Strong	141-205 mph	Severe tornado
F4	Violent	206-264 mph	Devastating tornado
F5	Violent	265+ mph	Incredible tornado

TORNADO LIFE CYCLE

As with thunderstorms, the tornado's life cycle can be divided into three stages.
Developing Stage - Most significant tornado circulations actually develop within the mesocyclone at about 20,000 feet above the ground. They gradually build down (and up) within the storm, reaching the ground several minutes later. Other tornado circulations develop at lower levels in the storm, perhaps at or below the level of the cloud base. In either case, as the circulation develops, a downdraft forms at the rear of the storm and descends, reaching the ground at about the same time as the tornado. It is believed that interaction between this downdraft, called a **rear-flank downdraft (RFD)**, and the mesocyclone is crucial in tornado formation.

Spotters observing a developing tornado will probably report a wall cloud with the following characteristics: **persistance**, vigorous persistent **rotation**, strong surface **inflow**, and rapid **vertical motions** in the cloud fragments. Spotters may or may not see a funnel cloud; their first indication that the tornado has reached ground will be a whirling cloud of dust and debris on the ground. See Figures 6-8 and 6-9 on the following page.

Mature Stage - A strong inflow of warm, moist air continues into the tornado as it develops and intensifies. The mature stage marks the strongest and most destructive stage of the tornado's life. During the mature stage, the tornado may grow to over a mile wide, with winds exceeding 250 miles an hour. Once the RFD strikes the ground, it begins **wrapping** around the west and south sides of the tornado and wall cloud. This wrapping of the RFD begins cutting off the inflow into the tornado. Spotters will likely see the visible funnel reach its maximum size. They may also see a **clear slot** form in the cloud base to the left of the wall cloud. This clear slot is caused by the RFD, and will move around the wall cloud from left to right. See Figures 6-10 and 6-11 on the following page.

Dissipating Stage - Eventually, the RFD will completely wrap around the tornado, and inflow into the tornado will become dissipated and cut off. At that point, the tornado enters the dissipating stage. The funnel will become smaller, it will tilt with height, and eventually will take on a contorted, snakelike shape. This is called the **rope stage**, and marks the final stage in the tornado's life. Spotters will need to beware at this stage for two reasons. First, although the tornado is dissipating, it is still dangerous. Second, if the supercell is cyclic, a new mesocyclone and wall cloud may form 2-3 miles east of the dissipating tornado. See figures 6-12 and 6-13.

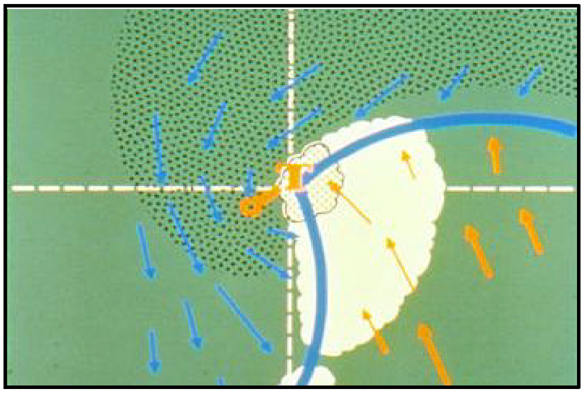


Figure 6-8: Diagram of developing tornado.

Figure 6-9: Example of developing tornado.

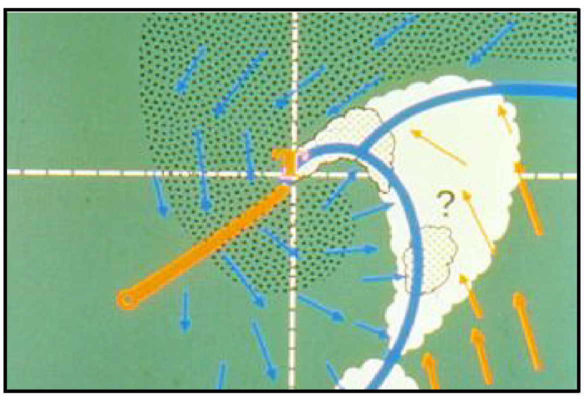


Figure 6-10: Diagram of mature tornado.

Figure 6-11: Example of mature tornado.

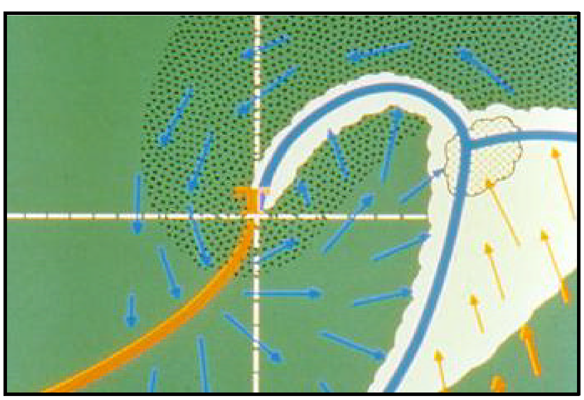


Figure 6-12: Diagram of dissipating tornado.

Figure 6-13: Example of dissipating tornado.

Tornado Variations - Tornadoes take on a variety of shapes and sizes, and they often change appearance during their lifetimes. They may assume the classic funnel shape, or they may be shaped like a cone or a large wedge. Some tornadoes are **multiple vortex** tornadoes, consisting of one large circulation with one or more smaller vortices embedded within it. Most large, destructive tornadoes have a multiple vortex structure. See figures 6-14 through 6-16.

Figure 6-14: Example of a large, wedge-shaped tornado.

Figure 6-15: Example of a tornado with a "classic" cone-shaped condensation funnel.

Figure 6-16: Example of a multiple-vortex tornado. This particular tornado had two vortices; tornadoes with up to 9 subvortices have been observed.